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PARTICLEBOARDS FROM LOWER GRADE HARDWOODS.(U)
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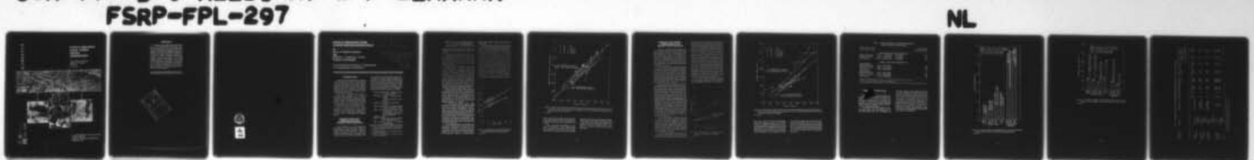

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PARTICLEBOARDS FROM LOWER GRADE HARDWOODS

USDA FOREST SERVICE
RESEARCH PAPER
FPL 297
JUNE 1977

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WIS.

ABSTRACT

Properties and characteristics are reviewed for particleboards prepared from hardwood residues of a number of species. In general, hardwood particleboards met or exceeded the minimum properties defined in Commercial Standard CS 236 for both Type 1 (interior) and Type 2 (exterior) applications. However, certain anomalies in the data suggest need for further research in the areas of wood-adhesive interactions, particularly with the higher density hardwoods. An appendix of research references is included for hardwood usage in composite panel products other than particleboard.

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PARTICLEBOARDS FROM LOWER GRADE HARDWOODS.[1/]

(9) Forest Service research paper,

By

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(12) 15p.

INTRODUCTION

Softwoods have generally been preferred to hardwoods as raw material for particleboard since the manufacture of this product began. However, hardwoods have also been used as particleboard furnish. Now, with shortages of softwood residues threatening, hardwood residues are likely to find increasing use in particleboard manufacture.

This paper reviews recent research, published and unpublished, in the area of hardwood particleboards. Levels of performance attained to date are illustrated. Also, research areas are indicated which demand further study to attain efficient use of hardwood residues in particleboard panels.

Only the use of hardwood in particleboards is discussed in this report. However, an appendix gives references to hardwood usage in fiber-base composite panels, such as in hardboard and insulation board.

INTERIOR-TYPE UREA-FORMALDEHYDE (UF) BONDED PARTICLEBOARDS

The properties of homogeneous flakeboards from four hardwoods—basswood, yellow-poplar, red oak, and hickory—were explored in one recent study (4).[3/] Flake raw material was obtained from cross-grain knife-planing of panel corestock. Variables other than species included flake thickness and panel density. The report supplied additional information on panels made from other flake and particle types. Panel production variables were similar to those which follow for "standard" U.S. Forest Products Laboratory (FPL) particleboards, except for minor changes to adapt to hardwood processing conditions:

Particle type and size: Flakes, 0.015 by 1 inch by random

Panel size: Rough—1/2 by 24 by 28 inches
Trimmed—1/2 by 22 by 26 inches

Density: 40 pounds per cubic foot (lb/ft^3)

Resin solids content: 6 percent (based on ovendry weight of wood)

Resin: 65 percent solids liquid urea-formaldehyde (UF) or 44 percent solids liquid phenol-formaldehyde (PF)

Catalyst: None

Wax: 1 percent wax emulsion (solids basis (PF boards only))

Mat moisture content: 10 percent (ovendry basis)

1/ A version of this paper was presented at the Utilization of Hardwood Residues Symposium, Champaign, Ill., October 17, 1975.

2/ Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

3/ Numbers in parentheses refer to Literature Cited at the end of this report.

141 700

Press cycle: UF—5 minutes at 325° F,
PF—10 minutes at 350° F
Press closing time: 1 minute to thickness

All tests were performed following procedures outlined in ASTM D-1037 as closely as possible.

Another study (7) was made in which four exotic hardwoods offering promise as particleboard furnish—kiri, virola, limba, and afrormosia—were used to produce three-layer particleboard. Other variables included degree of compression and mixture of the four species involved.

These studies indicated that bending properties (moduli of rupture, MOR, and elasticity, MOE) of particleboard specimens *could be accurately predicted from con*siderations of species density and desired panel density (figs. 1 and 2 and table 1). Report (7) also showed that bending properties of panels made with mixtures of species are directly correlated with weighted averages of the species comprising the mixture. This assumes some compression of the wood particles during the pressing cycle because compression is needed for satisfactory panels.

Internal bond strength levels also were correlated with density of source material (figs. 3 and 4 and table 1) but not with as high precision as MOR or MOE. The internal bond of panels made with mixtures of species is not as predictable as with single species, but generally tends to be controlled by the lowest density species in the mixture.

In dimensional stability tests, these studies (4,7) showed that thickness swelling and linear expansion are generally not predictable from density considerations. Usually higher density species will be more stable in thickness swelling and less stable in linear expansion than lower density species (figs. 5 and 6). Particle shape is of prime importance in controlling dimensional movements; particleboards with shorter particles produce less thickness swelling and more linear expansion than longer particles.

The studies showed that particleboards meeting the requirements of type 1B1 of the commercial standard for mat-formed particleboards, CS 236 (6), could be produced at densities of 34 to 37 lb/ft^3. The higher density woods generally required a proportionately higher panel density to attain a given performance level.

Table 2 indicates property levels attained with UF-bonded particleboards produced with *various hardwood residues; the data are from* recent unpublished studies conducted at FPL. Materials include aspen chips with bark, whole-tree mixed hardwood chips, turning residues from ash, and cross-grain planer flakes from both basswood and red oak. These materials were used to produce homogeneous or three-layer boards at 6 or 8 percent UF resin content. The data show that all panels except two would pass the requirements of CS 236. Those panels made from ash proved to be deficient in internal bond strength and probably linear expansion and thickness swell, and panels of basswood were deficient in internal bond strength. The panels prepared from aspen or mixed hardwood chips including bark are adequate in all properties,

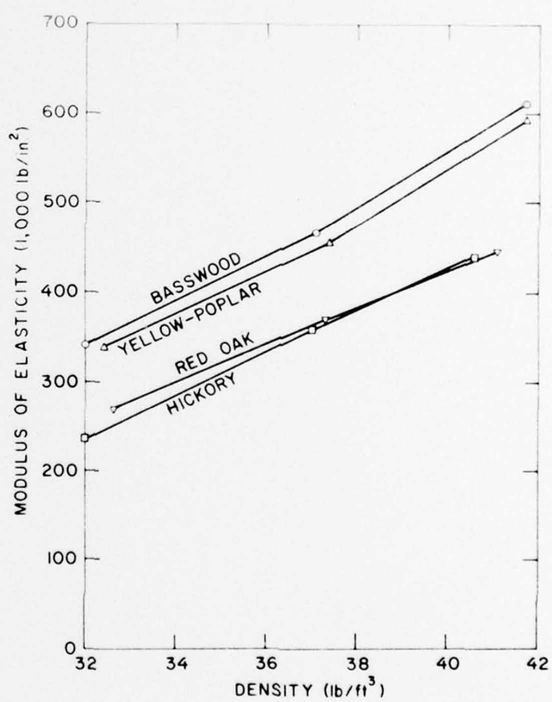

Figure 1.—Relationship of modulus of elasticity to species at various panel densities.
(M 140 105)

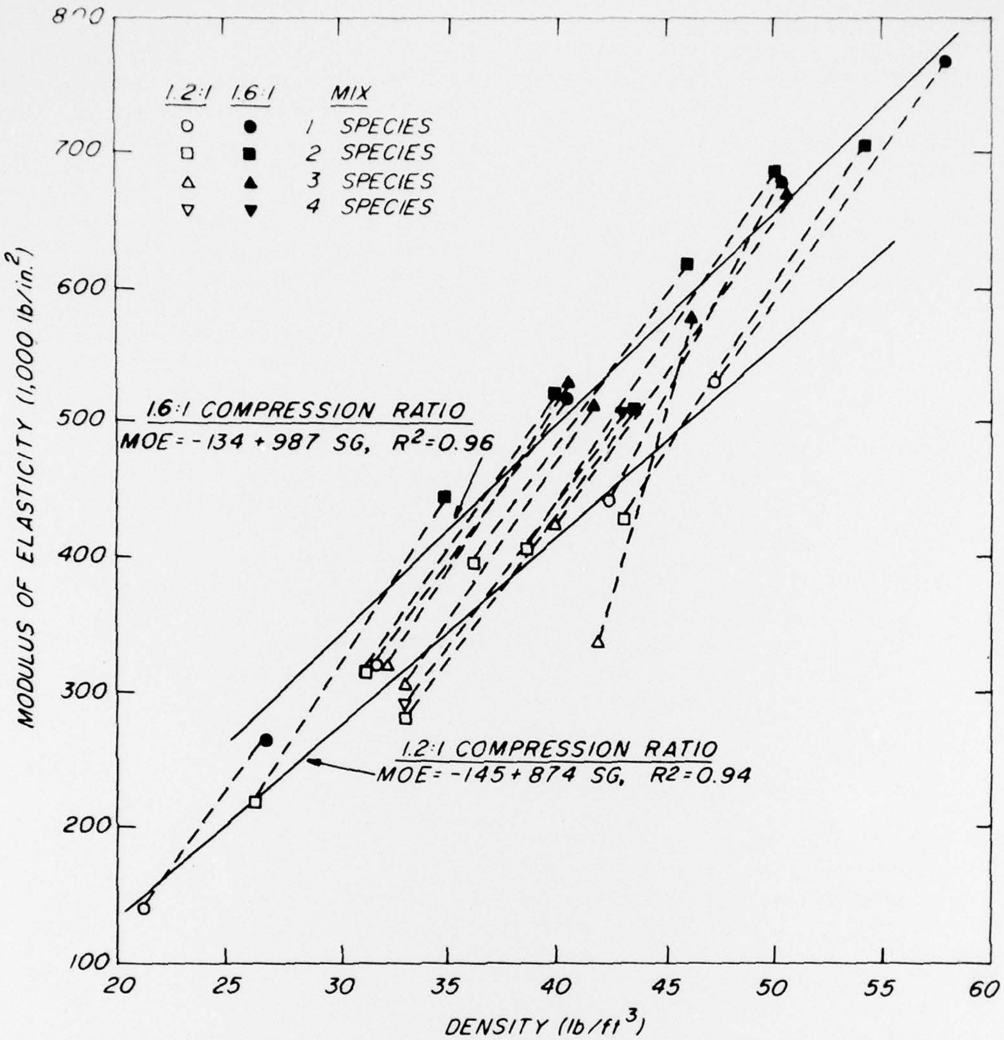

Figure 2.—Relationship of modulus of elasticity to board density as affected by species mixture and compression ratio of raw materials (7). The ratios 1.2:1 and 1.6:1 are ratios of panel density to species or species mix density.

(M 144 674)

and it may be shown that at equivalent densities these panels are similar in properties to hardwood panels previously studied (figs. 1 to 4) (4,7).

Thus, UF-bonded particleboard panels may be produced at normal densities and resin contents from small, lower grade hardwoods, including bark, which will meet the strength and stability requirements of CS 236. Note, however, that chips containing bark may contain amounts of silica or grit sufficient to produce machining problems either in the flaking or panel trimming and cutting operations.

EXTERIOR-TYPE, PHENOL-FORMALDEHYDE (PF) BONDED PARTICLEBOARDS

Previously unreported data resulting from tests of panels made at FPL with larger flakes and bonded with phenol-formaldehyde resin are summarized in table 3. The data are obtained from panels of aspen, elm, maple, and red oak in homogeneous or three-layer construction at densities of 35 to 45 lb/ft^3 and with 3 to 7 percent PF resin. The data are from four small exploratory studies and are thus labeled as groups 1 through 4.

The first group was comprised of several relatively low-density aspen panels made with various flake types and bonded with 3 percent PF resin. Only the second panel in this group would meet the requirements of type 2B2 of CS 236. The inclusion of bark in this panel type resulted in reduced strength levels in all tests. Also, the use of thick (0.03 in.) flakes produced more thickness swell and linear expansion than with thin (0.015 in.) flakes.

The second group illustrates properties of three-layer panels bonded with 3,4, or 5 percent PF resin at 35-, 40-, or 45-lb/ft^3 density. These panels were prepared from material obtained from boles of small aspen trees and, with one exception, were prepared with naturally occurring amounts of bark. The data concerning tree sizes and wood and bark contents pertinent to this group are summarized in table 4. Some material was disk-flaked and milled (fig. 7) for use in panel faces, and the remainder was chipped and milled to splinter shapes for core material. All panels would meet the type 2B2 requirements of CS 236. Panel density had a more pronounced effect on strength and stiffness levels than did resin content, although increased resin content improved retention of internal bond after the accelerated aging test.

Other trends noted in this group of panels included the general improvement in properties when bark was omitted from the raw material mix. Also, the strength properties of panels made with material of less than 2-inch diameter were equivalent to those from panels made with bole wood, but linear expansion was increased in the panels made with the smaller diameter material.

The third group of panels was made with cross-grain planed flakes of red oak at 5 or 7 percent PF resin and 40- or 45-lb/ft^3 density. Several factors were notable in this series of panels. Only the high-density panels would meet the requirements for type 2B2 panels of CS 236, thus indicating a substantial change in panel properties due to a species change. A significant increase in internal bond strength occurred in changing from aspen to red oak, but this should be expected because of the greater inherent strength of the oak. On the average, linear expansion with oak panels was twice that obtained with the aspen, again probably caused by greater inherent instability in the oak. The major change, however, was the loss in strength following the accelerated aging test. This was 50 percent in MOR but 97 percent in internal bond, both significantly decreased from levels attained with aspen. These data indicate that much research will be necessary to determine techniques of obtaining durable bonds with minimum adhesive contents in higher density hardwoods.

The fourth and final group illustrates properties attained with bark-free material of small diameter (less than 6 in.) comprised of

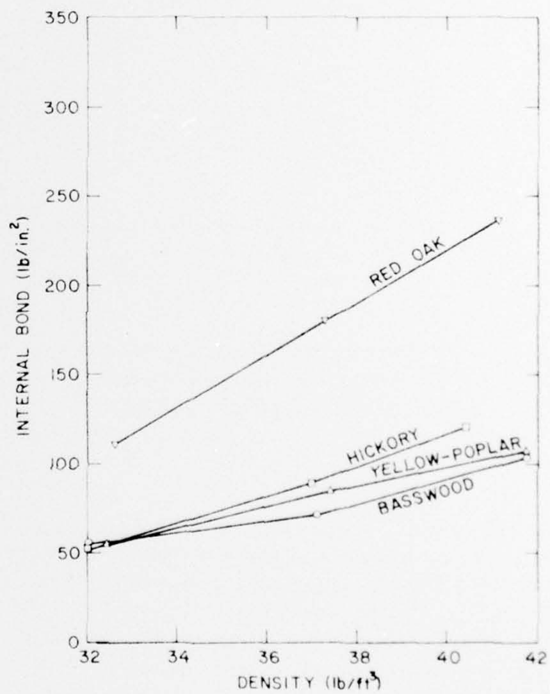

Figure 3.—Relationship of internal bond to species at various panel densities.
(M 140 106)

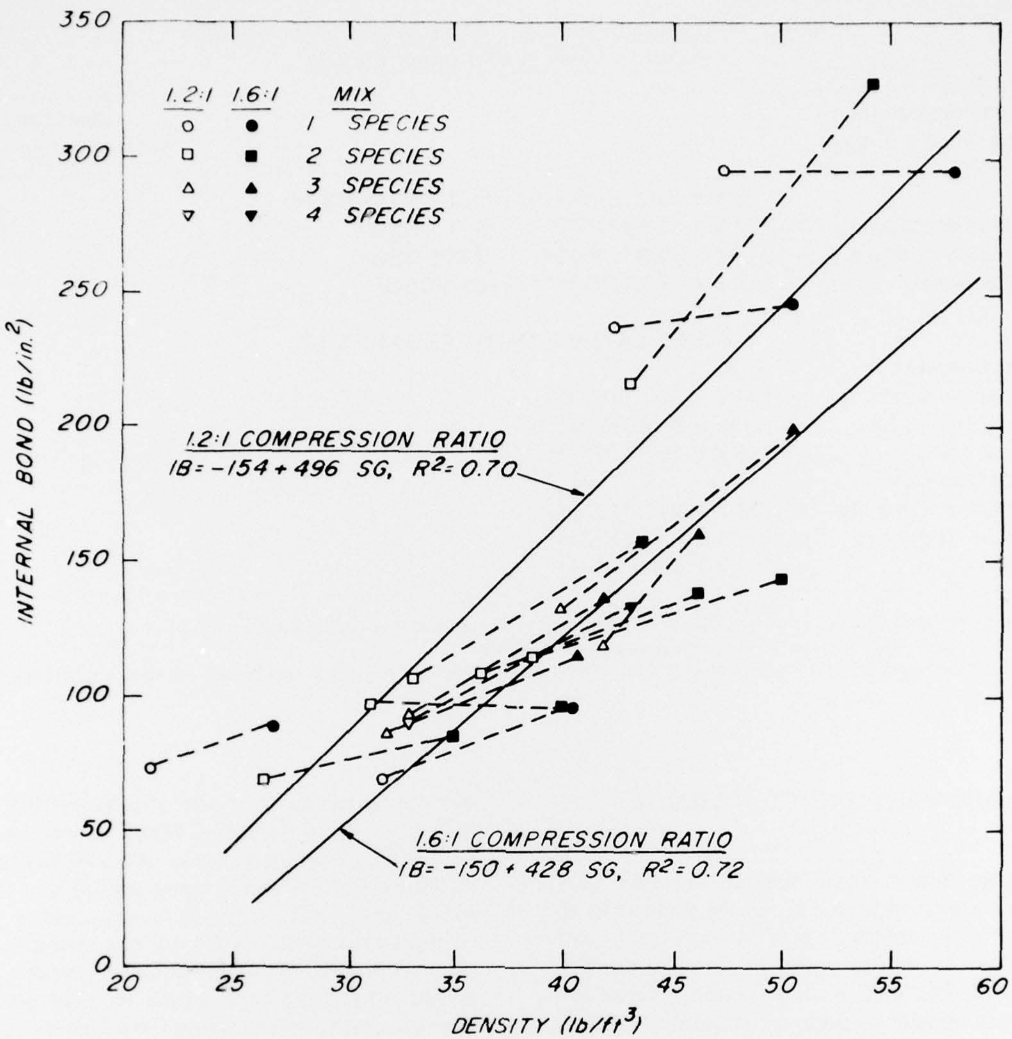

Figure 4.—Relationship of internal bond to board density as affected by species mixture and compression ratio of raw material (7). The ratios 1.2:1 and 1.6:1 represent the ratios of panel density to species or species mix density.
(M 144 675)

aspen, elm, maple, or a mixture of these species at two densities (either 35 or 40 lb/ft^3). In terms of meeting the requirements of type 2B2 particleboard, the aspen again performed adequately at both densities, elm at neither, and maple and the mixture only at the higher density. Because of elm's anatomical structure, it tends to flake into numerous narrow, strandlike particles rather than into wider flakes. This increases the particle surface area per unit weight proportionately and manifests itself in less adhesive per unit area and reduced internal bond levels after the accelerated aging test.

Table 1.—Strength properties[1/] of hardwood particleboard related to species and panel density

Regression equations ($y = a + bX_1 + cX_2$)		Coefficient of determination (R^2)
	HOMOGENEOUS PARTICLEBOARDS (4)	
Modulus of elasticity	= -278.5 + 1,564 PSG[2/] -441.0 SSG[2/]	0.94
Modulus of rupture	= -3,347 + 12,855 PSG[2/] -2,495 SSG[2/]	.91
Internal bond	= -283.1 + 492.8 PSG[2/] +181.1 SSG[2/]	.42
	THREE-LAYER PARTICLEBOARDS (7)	
Lower Density[3/]		
Modulus of elasticity	= -144.7 + 873.7 PSG[2/]	.94
Modulus of rupture	= -1,439 + 7,127 PSG[2/]	.96
Internal bond	= -154.2 + 496.0 PSG[2/]	.70
Higher Density[3/]		
Modulus of elasticity	= -133.7 + 987.0 PSG[2/]	.96
Modulus of rupture	= -1,504 + 8,428 PSG[2/]	.98
Internal bond	= -150.2 + 427.6 PSG[2/]	.72

1/ Modulus of elasticity measured in 1,000 lb/in.^{2}, modulus of rupture and internal bond in lb/in.^{2}

2/ PSG = panel specific gravity; SSG = species specific gravity.

3/ Lower density panels have a panel density 1.2 times the species density, higher density panels 1.6 times species density.

SUMMARY AND CONCLUSION

Th[illegible] indicate that UF-bonded particleb[illegible]ardwood can be produced at almo[illegible] desired level of strength and stiffness by adjustment of manufacturing variables. The use of lower grade hardwoods does not appear to pose a problem to performance in this type of panel.

The studies of PF-bonded hardwood panels have shown that the addition of an accelerated aging test (as an indication of durability) places a much greater burden on the panel manufacturer. Many more factors should be considered when using PF resins as compared to UF resins because the end uses more likely will impose more harsh environments on the panels. By proper selection of particle size, resin content, and density, it is possible to attain high levels of initial performance with PF-bonded hardwood particleboards. However, more research is needed to learn how to effectively control durability in this type of particleboard.

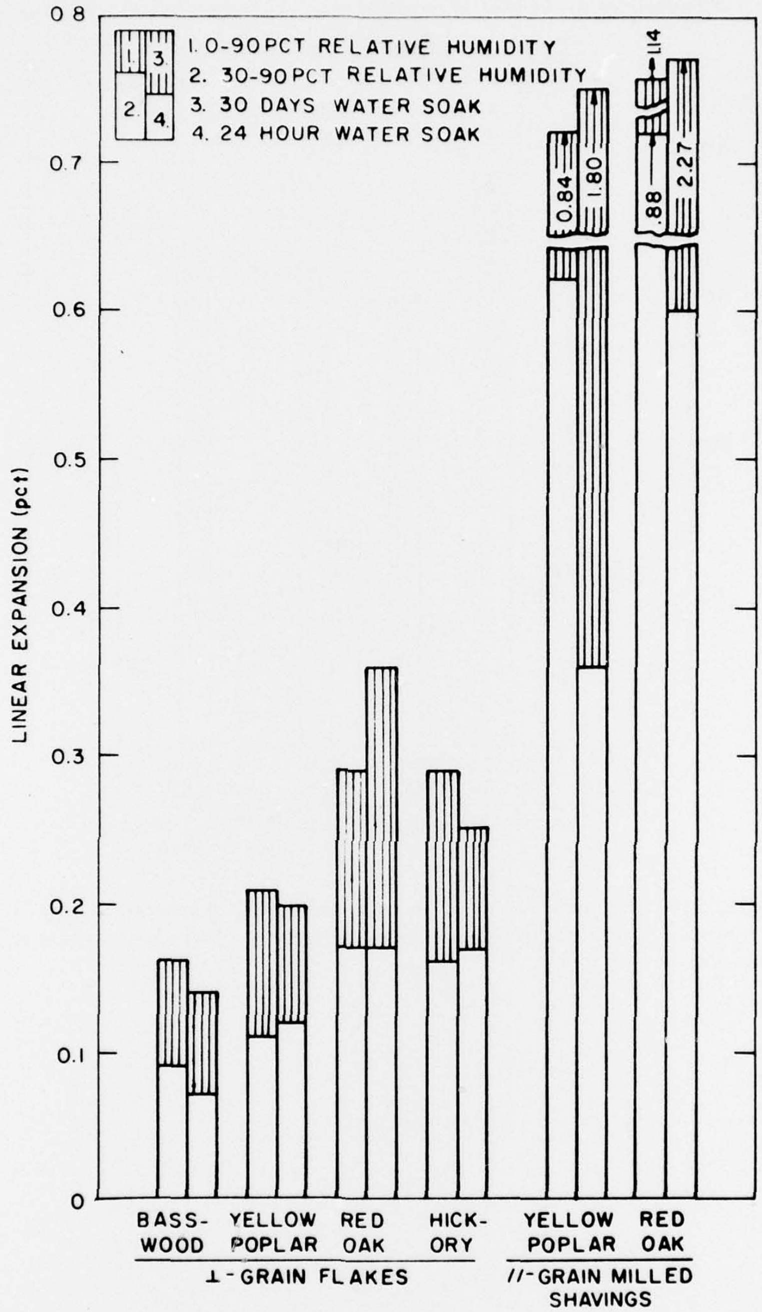

Figure 5.—Linear stability of particleboards from various species and particle types in relative humidity and watersoak tests.

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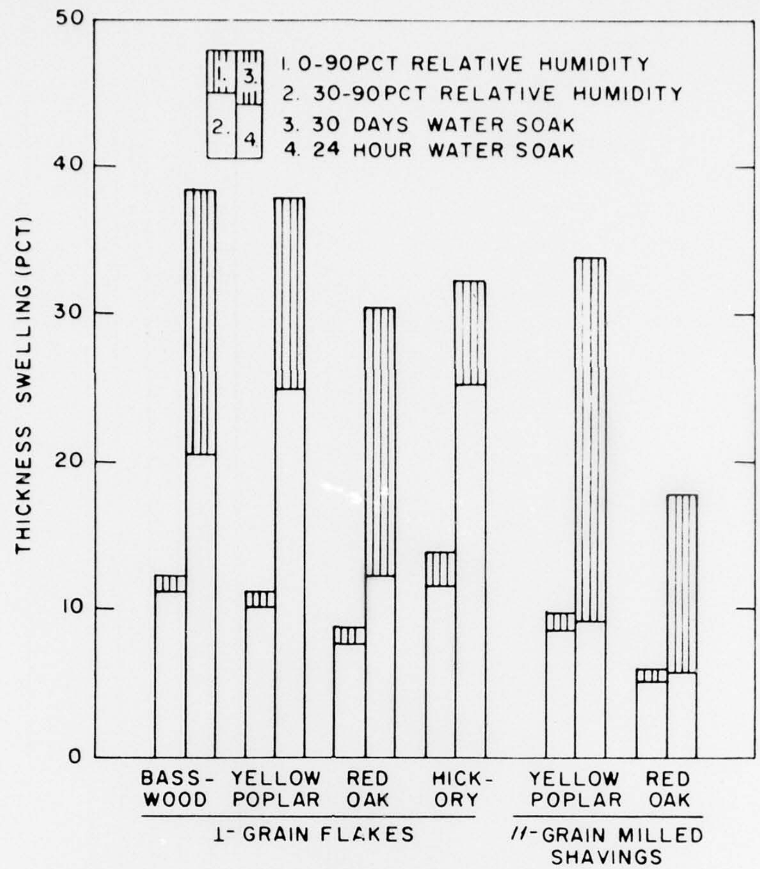

Figure 6.—Thickness stability of particleboards made from various species and particle types in relative humidity and watersoak tests.
(M 144 676)

Table 2.—Properties of various hardwood particleboards[1] bonded with urea-formaldehyde resin

Species	Particle	Construction	Resin	Wax	Density[2]	Modulus of rupture	Modulus of elasticity	Internal bond	Ovendry-vacuum pressure soak[3]	
									Linear expansion	Thickness swelling
			Pct	Pct	Lb/ft³	Lb/in.²	1,000 lb/in.²	Lb/in.²	Pct	Pct
Aspen with bark	0.015- by 0.5-inch ring flake	Homogeneous	6	1	36.2	2,850	381	127	0.65	35.0
Do.	. . . . .do.	Three-layer	6	1	36.8	3,010	384	94	.66	40.1
Mixed with bark	0.015- by 1-inch ring flake	Homogeneous	6	1	37.4	2,850	366	122	.61	38.1
Do.	. . . . .do.	Three-layer	6	1	38.1	3,040	328	134	.70	33.8
Basswood	0.015- by 1-inch cross-grain flake	Homogeneous	8	1	34.9	2,910	465	49	.24	24.3
Do.	. . . . .do.	. . . . .do.	8	1	38.7	3,700	547	33	.20	25.8
Red oak	. . . . .do.	. . . . .do.	8	1	38.1	2,950	396	110	.39	23.4
Do.	. . . . .do.	. . . . .do.	8	1	43.1	4,140	518	146	.44	23.8
Ash	Milled turning flake	. . . . .do.	6	1	34.9	2,040	318	18	1.16	91.6

1/ All data reported are derived from 4 to 8 test specimens.
2/ Ovendry weight divided by volume at test.
3/ Total movement between ovendry and wet conditions.

Table 3.—Properties of various hardwood particleboards[1] bonded with phenol-formaldehyde resin

Species	Particle	Construction	Resin	Wax	Initial: Density[3]	Initial: Modulus of rupture	Initial: Modulus of elasticity	Initial: Internal bond	After accelerated aging: Density	After accelerated aging: Modulus of rupture	After accelerated aging: Modulus of elasticity	After accelerated aging: Internal bond	Ovendry-vacuum pressure soak[2]: Linear expansion	Ovendry-vacuum pressure soak[2]: Thickness swelling
			Pct	Pct	Lb/ft³	Lb/in.²	1,000 lb/in.²	Lb/in.²	Pct	Pct	Pct	Pct	Pct	Pct
GROUP 1														
Aspen	0.015- by 2-inch cross-grain flake	Homogeneous	3	1	34.9	2,470	379	82	—	—	—	—	0.19	37.8
Do	0.015- by 2-inch ring flake	do	3	1	35.6	3,320	579	68	—	—	—		23	37.6
Do	0.030- by 2-inch ring flake	do	3	1	36.8	2,390	333	70	—	—	—	—	40	60.6
Aspen with bark	0.015-by 2-inch ring flake	do	3	1	33.7	2,300	372	58	—	—	—	—	26	36.1
GROUP 2														
Aspen with bark (2-in. diameter)	0.020- by 2-inch disk flake faces and milled chip core	Three-layer	3	1	34.9	3,420	539	57	79	60	65	18	24	24.2
Do	do	do	3	1	40.0	4,180	676	75	74	77	64	12	—	31.0
Do	do	do	3	1	45.0	4,980	723	82	76	82	92	13	25	33.2
Do	do	do	4	1	34.9	3,030	500	55	78	72	70	33	27	20.9
Do	do	do	4	1	40.0	3,450	535	73	70	73	74	29	32	23.2
Do	do	do	4	1	45.0	4,910	706	98	69	66	61	—	22	27.9
Do	do	do	5	1	34.9	3,030	460	69	76	77	87	41	26	20.3
Do	do	do	5	1	40.0	4,060	592	82	71	72	97	30	26	22.3
Do	do	do	5	1	45.0	5,140	718	103	65	51	89	17	29	23.9
Do	do	do	5	1	40.0	3,950	594	82	76	72	81	29	36	21.6
Aspen without bark (2-in. diameter)	do	do	5	1	40.0	4,720	644	136	77	87	93	43	26	26.5
GROUP 3														
Red Oak	0.015- by 2-inch cross-grain flake	Homogeneous	5	1	41.8	2,550	402	134	67	51	54	3	53	25.2
Do	do	do	5	1	45.0	3,440	467	189	64	51	60	3	56	27.2
Do	do	do	7	1	40.6	2,670	403	116	88	48	61	3	53	21.7
Do	do	do	7	1	45.0	3,590	505	172	68	50	59	3	56	21.9

GROUP 4														
Aspen	0.020- by 2-inch ring flake	do.	5	1	36.2	3,550	498	74	79	83	91	38	21	26.2
Do.	do.	do.	5	1	41.2	4,510	620	83	70	76	86	23	24	33.3
Elm	do.	do.	5	1	35.6	2,380	341	83	72	59	63	19	28	30.4
Do.	do.	do.	5	1	40.0	3,170	422	115	73	69	79	14	33	31.2
Maple	do.	do.	5	1	36.2	2,440	375	77	79	77	69	44	40	25.5
Do.	do.	do.	5	1	41.2	3,890	494	103	80	75	78	44	38	29.7
Mix: Aspen, elm, maple	do.	do.	5	1	36.2	3,110	420	69	76	66	74	38	28	29.0
Do.	do.	do.	5	1	41.2	3,580	492	86	76	86	90	36	27	30.8

1/ All data reported are derived from 4 to 8 test specimens.
2/ Total movement between ovendry and wet conditions.
3/ Ovendry weight divided by volume at test.

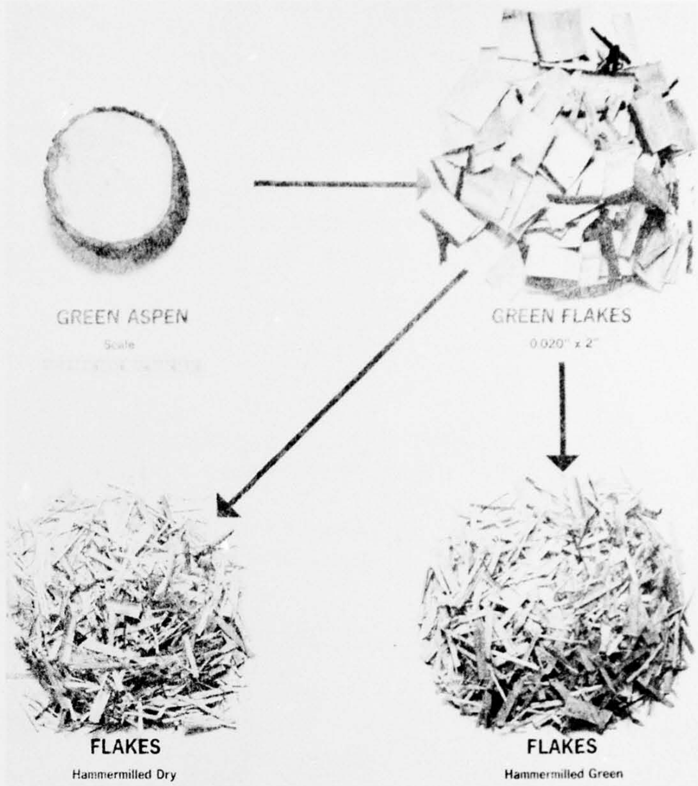

Figure 7.—Production of aspen face flakes in whole tree utilization study (table 3, group 2).

(M 141 290)

Table 4.—Physical properties of aspen trees[1]

Portion of tree	Fraction by weight		
	Total[2]	Wood[3]	Bark[3]
	Pct	Pct	Pct
Stems	70	78	22
Tops	18	64	36
Branches	12	74	26

1/ Based on 6 trees, 4.5-in. average diameter at breast height, 24-ft average height, 23-year age.
2/ Weight as harvested.
3/ Ovendry weight basis.

APPENDIX

Publications From Forest Products Laboratory Relating To Use of Hardwoods in Fiber-Base Composite Panels

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Particleboards from lower grade hardwoods, by Bruce G. Heebink and William F. Lehmann, Madison, Wis., FPL, 1977.
12 p. (USDA For. Serv. Res. Pap. FPL 297).

Properties and characteristics are reviewed for particleboards prepared from hardwood residues of a number of species.

KEYWORDS: Adhesive, hardwoods, particleboard, strength properties, wood residues.

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